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EMPIRICAL MODELING OF THE THERMOSPHERE: AN OVERVIEW

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Hedin gave a summary of thermospheric density modeling history and standard atmospheres. In particular, he compared and contrasted the approaches of the Jacchia and MSIS models. His conclusions were that the Jacchia models are best if drag is the primary concern. MSIS is superior for variations in composition and temperature variations and comparison with theoretical models is facilitated by the use of spherical harmonics, which also provide a simple and consistent way of obtaining simplifications.

ADVANTAGES/DISADVANTAGES

1. Jacchia

    a. Theoretically best if drag is primary quantity desired without high resolution and for satellite geometries and orbits similar to those used in generating the model. However, drag coefficients used in density derivation need to be more carefully specified if original drag is to be reproduced. Inaccurate specification of composition (e.g. He bulge) may result in inaccurate drag.

    b. Absolute total density dependent on the drag coefficient rather than the instrument calibration. However, dependence of drag coefficients on composition and extreme geometries may be a problem. Model predictions of composition and temperature are derived from auxiliary data or assumptions and may not be realistic.

    c. Formulation has particular difficulty coping with minor constituent variations found by mass spectrometers and cumbersome pseudotemperatures of J77 help only a little.

2. MSIS

    a. Best for composition/temperature variations, but agrees with drag models in overall averages.

    b. Provides better resolution of variations (including total density) in local time, etc.

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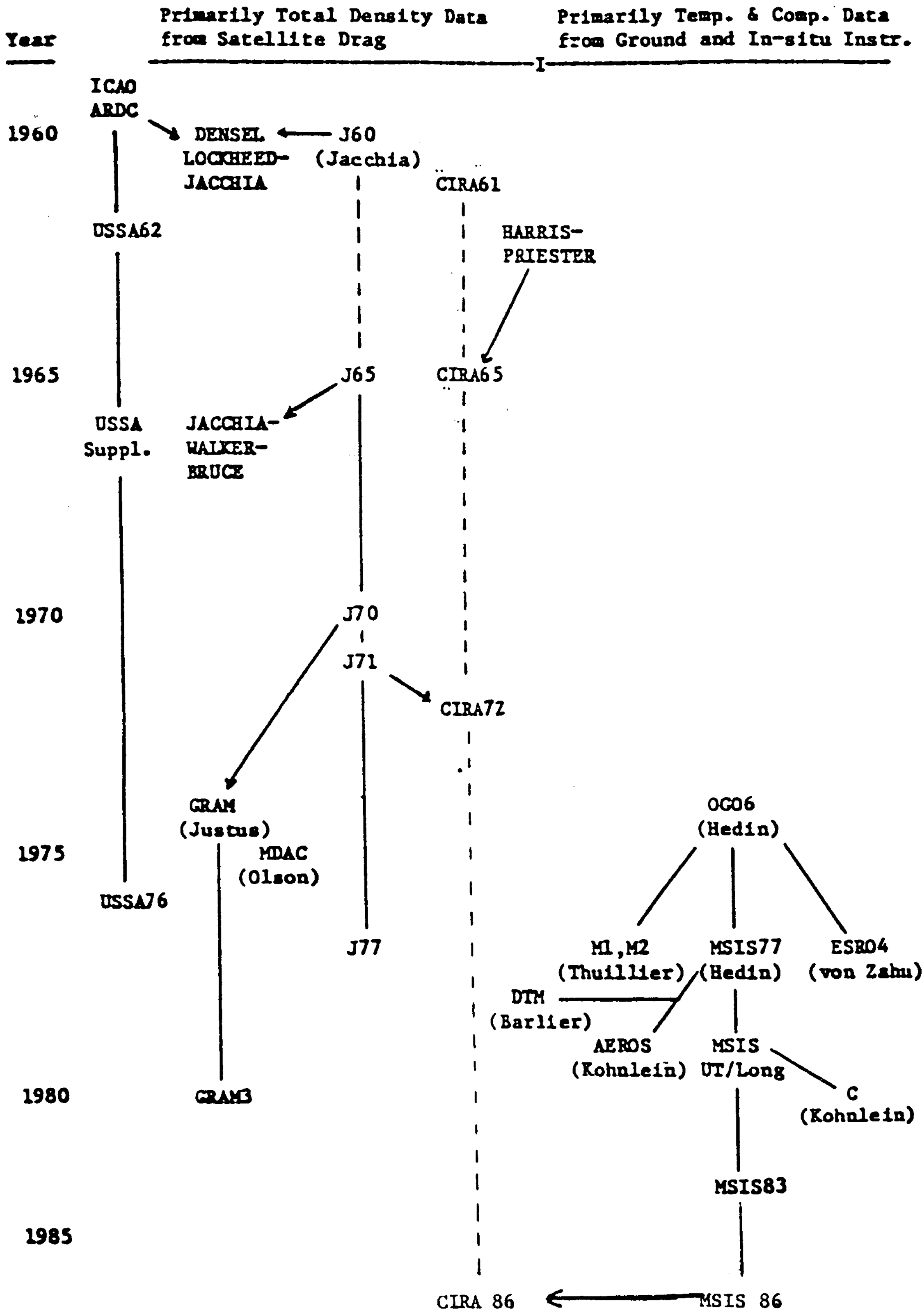
c. Absolute densities dependent on individual calibration constants for contributing instruments but model accuracy should be better than that of an individual instrument.

d. Spherical harmonics facilitate systematic increase in model resolution and comparison with theoretical models. Similarly, complexity can be reduced if desired by dropping higher harmonics or unneeded effects.

e. No numerical integration for faster execution speed.

Historical Development of Empirical Thermosphere Models



MODEL DEVELOPMENT

A. Jacchia
1. J65
   a. Earliest comprehensive model based on drag. Lower boundary at 120 km.
   b. Static height profiles as function of exospheric temperature assuming hydrostatic/diffusive equilibrium.
   c. First to include four principal effects (diurnal/seasonal, semiannual, solar activity, magnetic activity) using ad hoc formulas for exospheric temperature to fill gaps.
   d. Introduced Bates type temperature profile (which can be integrated explicitly).
2. J70 & J71
   a. Lower boundary at 90 km and more complicated temperature profile requiring numerical integration.
   b. Refinements and expansions of ad hoc formulas.
   c. Included factor of three winter helium bulge.
   d. J71 raised atomic oxygen at 150 km over J70.
3. J77
   a. Inclusion of some results from mass spectrometers.
   b. Magnetic coordinates for magnetic activity effects.
   c. Composition phase through pseudo-temperatures.

B. OGO-6/MSIS
1. OGO-6 (1974)
   a. Earliest comprehensive model based on mass spectrometer data.
   b. Bates temperature profile above 120 km.
   c. Spherical harmonics for geographical/local time coordinates.
   d. Variable boundary at 120 km for He and O to represent phase differences between constituents. Height profiles assuming hydrostatic/diffusive equilibrium.
   e. Temperature inferred from N2 agreed well with incoherent scatter.
2. MSIS 77
   a. Same format as OGO-6.
   b. Used mass spectrometer density data from five satellites and temperatures from four incoherent scatter stations.
   c. Variable boundary also for N2 so temperature depends on incoherent scatter and N2 scale heights.
3. MSIS 79
   a. Introduced UT/Longitude variations for quiet and magnetic active times (alternative to magnetic coordinates). Temperature maximum and He minimum near magnetic pole.
4. MSIS 83
   a. Density and temperature data from mass spectrometers on seven satellites, from five IS stations, and from rockets.
   b. Extended profiles below 120 km to 85 km using analytically integrable temperature profiles.
   c. Includes major variations in temperature and density below 120 km.
   d. Improved resolution in prediction of magnetic activity variations using time history of 3hr indicies.

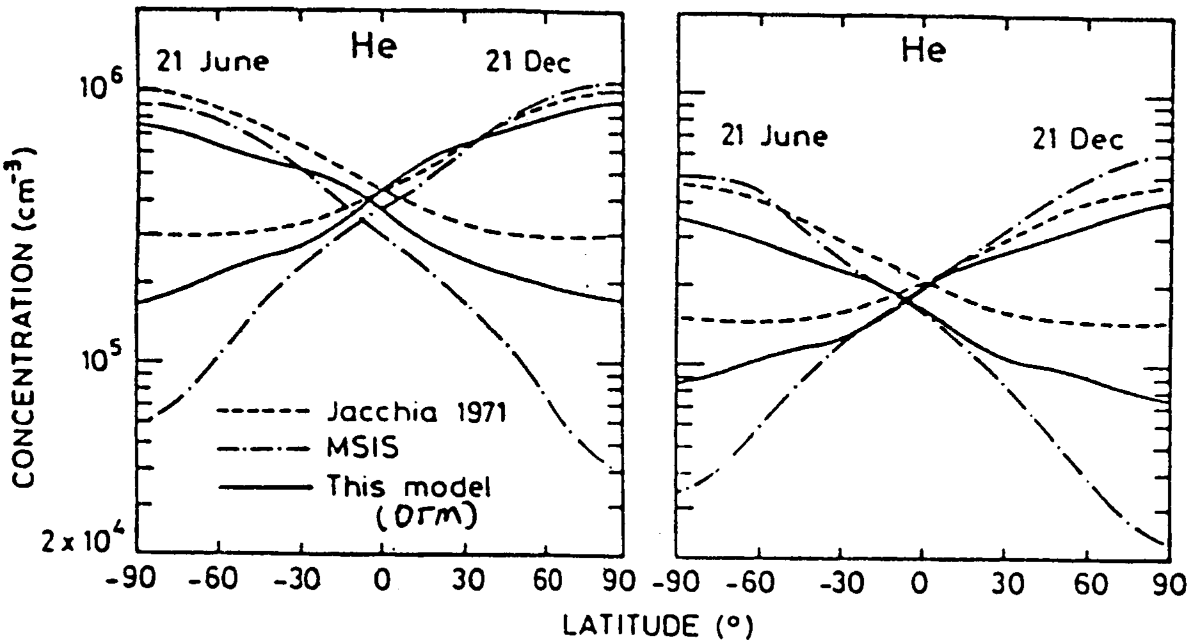


Fig. 13

Latitudinal variation of $n(He)$ at 1 000 km altitude. The left part corresponds to $F = \bar{F} = 150 \times 10^{-22}$ W m^{-2} Hz^{-1} and $K_p = 2$. The right part corresponds to $F = \bar{F} = 92 \times 10^{-22}$ W m^{-2} Hz^{-1} and $K_p = 2$. Comparison with Jacchia 1971 and MSIS models. Barlier (1979)

EXOSPHERIC TEMPERATURE DISTRIBUTION AT NORTHERN SUMMER SOLSTICE
Jacchia J71 Model

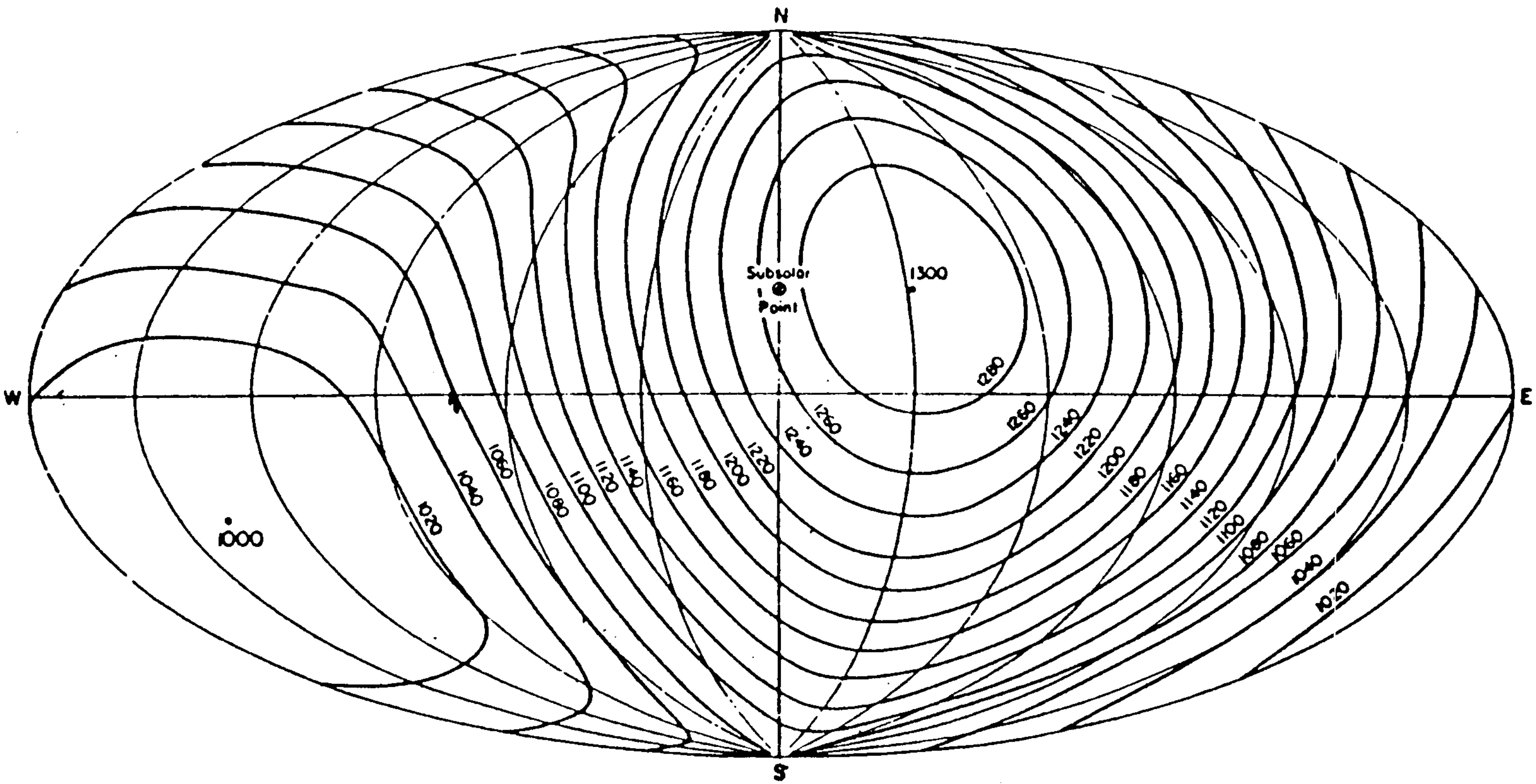
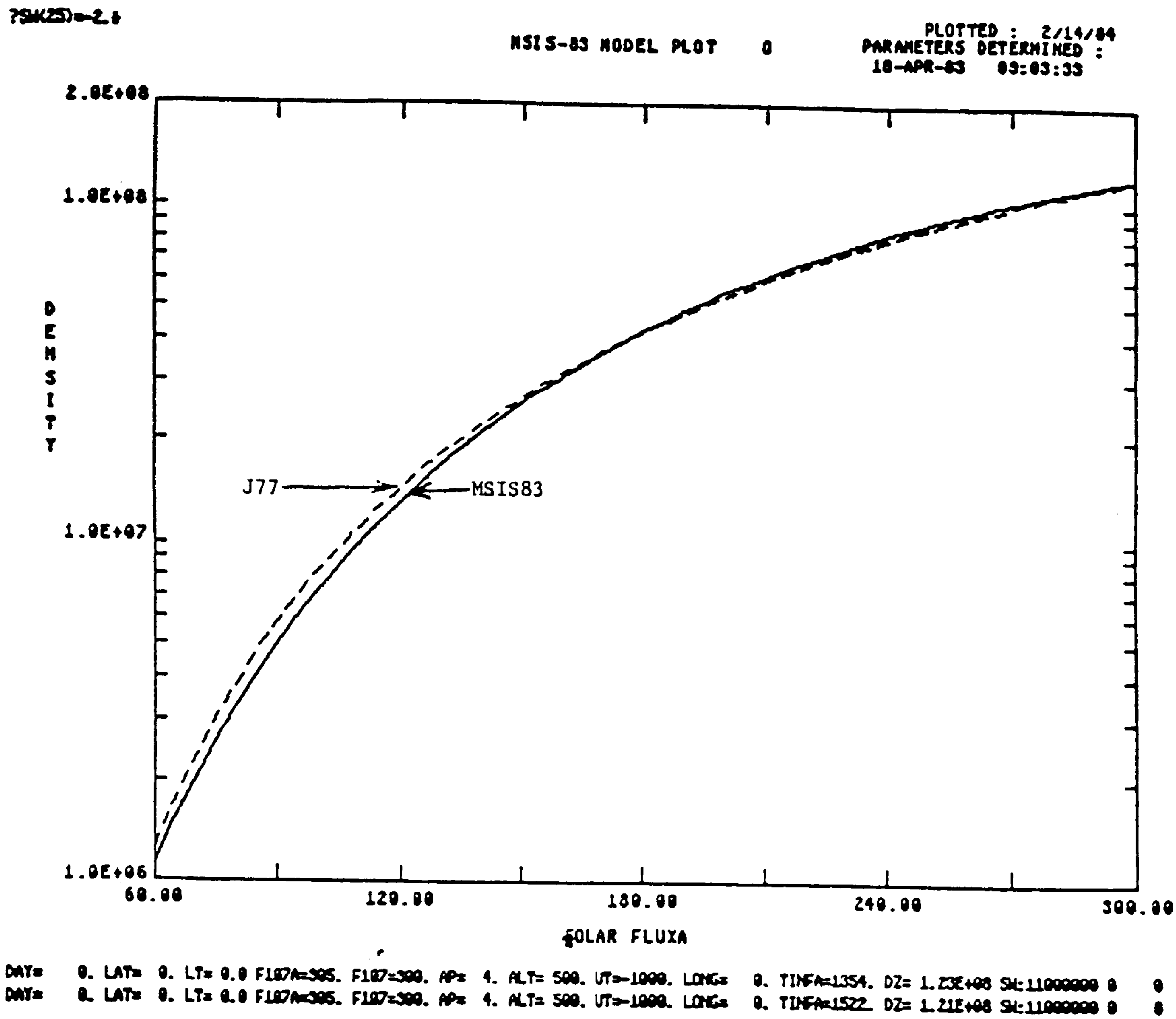


Figure 8. Exospheric isotherms (°K) above the globe, computed from equations (15) and (16), for the case when the minimum temperature is 1000°K. Aitoff's equal-area projection; meridians of local solar time and parallels of latitude are drawn 30° apart. Top, equinoxe bottom, northern summer solstice.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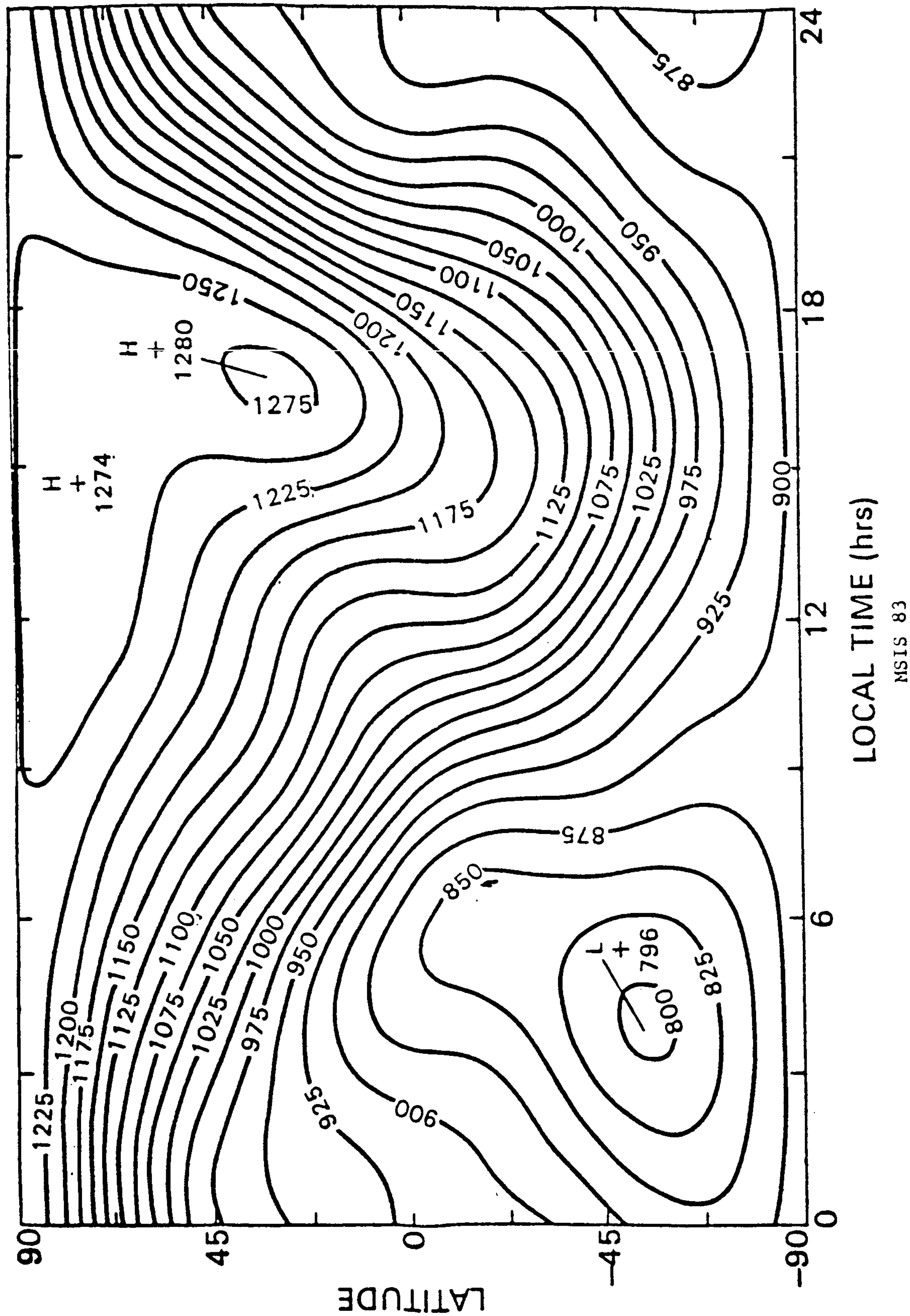
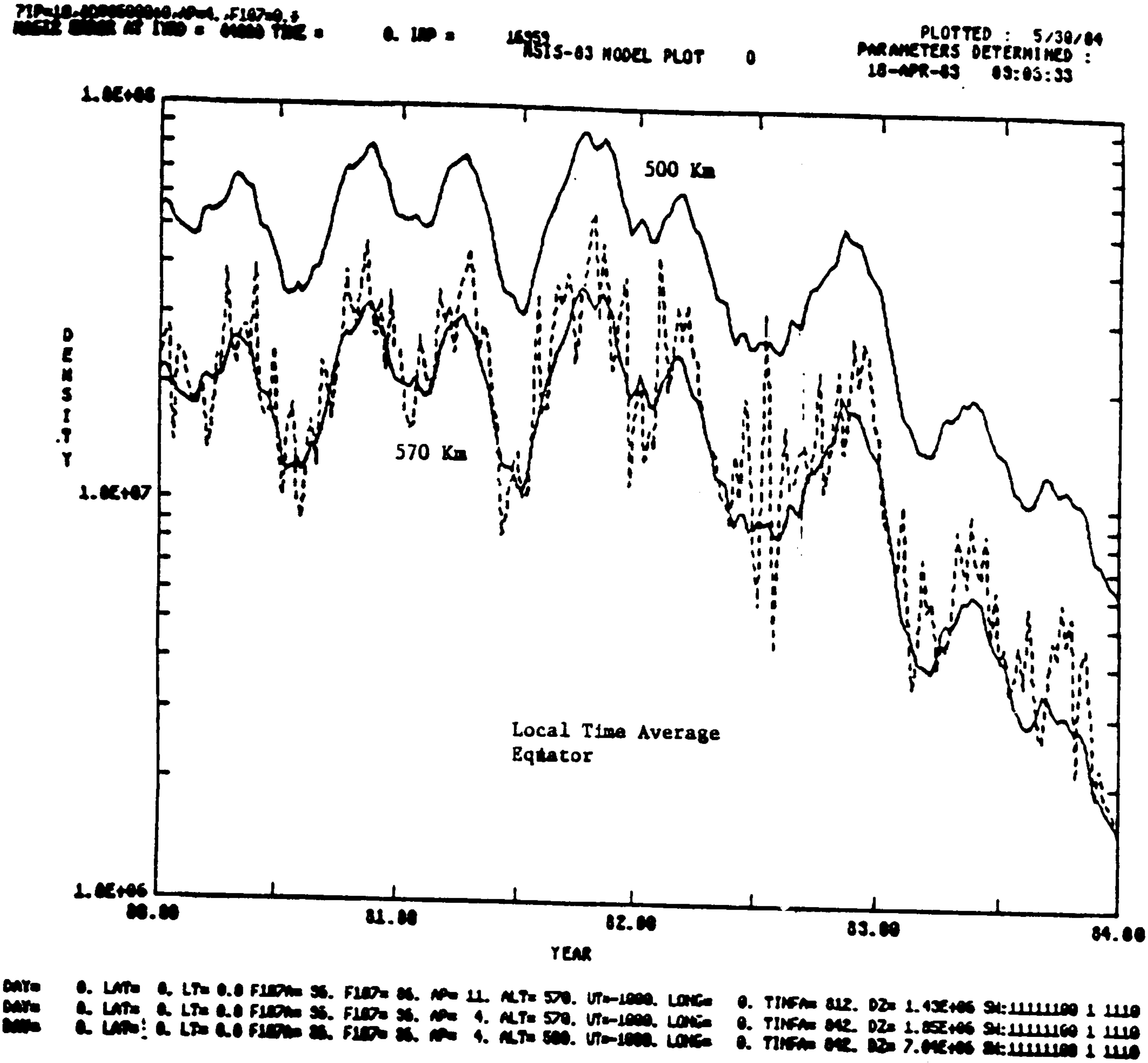
PARAMETERS DETERMINED :
18-APR-83 09:03:33
2.0E+08
1.0E+08
1.0E+07
1.0E+06
DENSITY
J77
MSIS83
60.00
120.00
180.00
240.00
300.00
SOLAR FLUXA
DAY= 0. LAT= 0. LT= 0.0 F107A=305. F107=300. AP= 4. ALT= 500. UT=-1000. LONG= 0. TINFA=1354. DZ= 1.23E+08 SW:11000000 0 0
DAY= 0. LAT= 0. LT= 0.0 F107A=305. F107=300. AP= 4. ALT= 500. UT=-1000. LONG= 0. TINFA=1522. DZ= 1.21E+08 SW:11000000 0 0


LATITUDE
90
45
0
-45
-90
0
6
12
18
24
LOCAL TIME (hrs)
MSIS 83
H
1274
H
1280
1275
L
796
800
825
850
875
900
925
950
975
1000
1025
1050
1075
1100
1125
1150
1175
1200
1225
1250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18-APR-83 09:05:33
1.0E+08
1.0E+07
1.0E+06
DENSITY
500 Km
570 Km
Local Time Average
Eqiator
80.00
81.00
82.00
83.00
84.00
YEAR

Table 4a. Density Ratio to MSIS-83 for N_2, O, and He.

		N_2			O			He		
Data Set	altitude	avg	sd	pts	avg	sd	pts	avg	sd	pts
OGO-6 (MS)	400-700	1.08	.27	659	1.15	.16	1276	1.18	.19	902
San Marco-3 (MS)	190-250	1.10	.20	77	.86	.15	24	1.09	.17	41
Aeros-A NATE (MS)	200-500	1.13	.47	321	1.14	.33	478	1.18	.42	466
AE-C NATE (MS)	190-400	1.13	.33	640	.91	.18	866	.68	.18	855
AE-C OSS (MS)	135-160+	.97	.15	440						
AE-C OSS (MS)	190-400	1.02	.26	319	1.08	.18	387	1.03	.23	371
AE-D OSS (MS)	140-160+	.99	.16	184						
AE-D OSS (MS)	190-400	.87	.33	99	1.01	.18	107	.78	.22	107
AE-E NACE (MS)	140-160+	1.01	.13	815						
AE-E NACE (MS)	190-450	1.00	.22	701	.87	.18	1019	.93	.17	1002
ESRO-4 (MS)	200-350	.88	.33	427	.83	.24	587	.84	.30	518
Rockets (MS)	100-120	.83	.36	35						
Rockets (MS)	110-160	.92	.30	28						
Rockets (MS)	190-300	.90	.32	39						
Arecibo (IS)	100-120	.92	.32	228						
Arecibo (IS)	110-135	1.14	.51	109						

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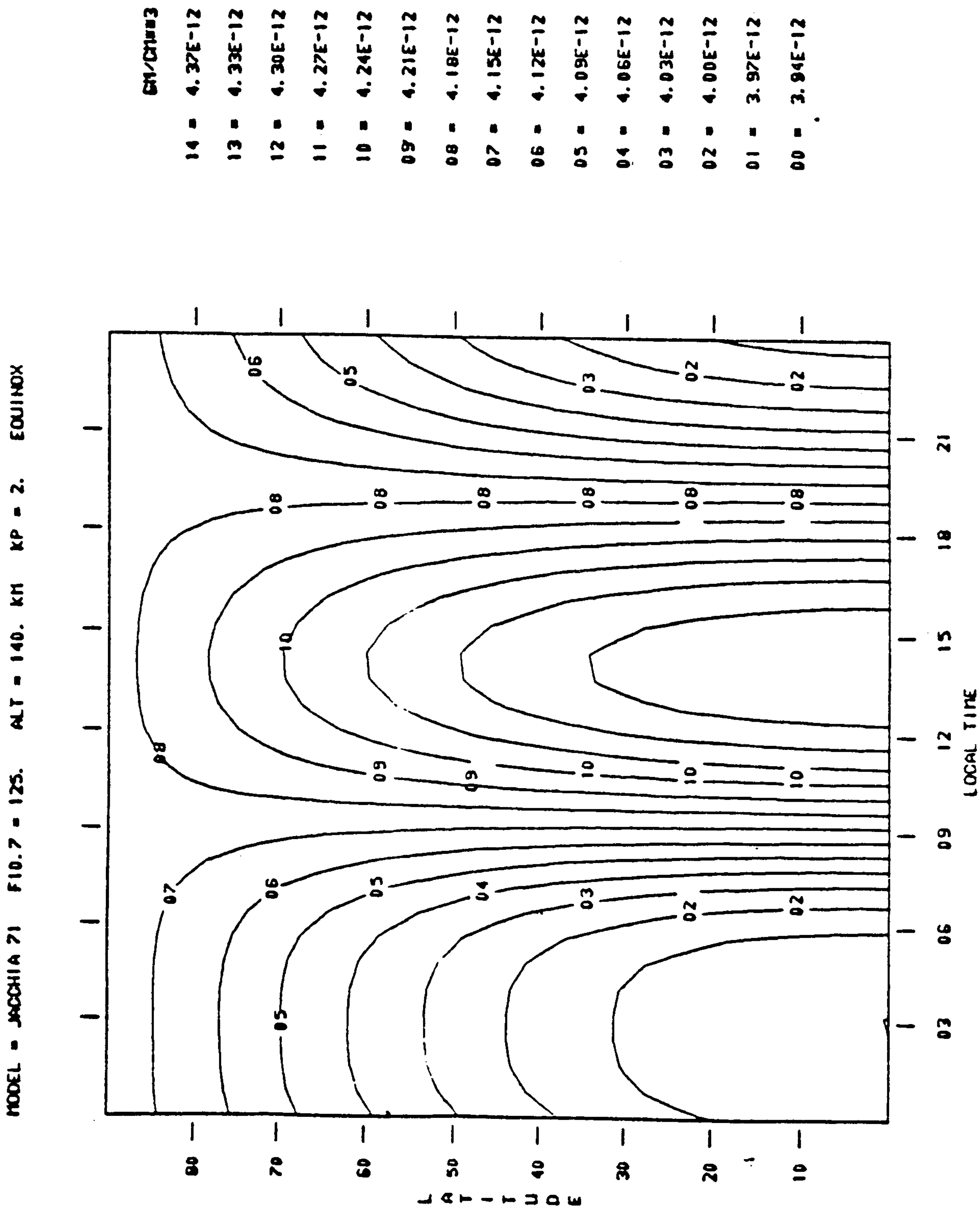

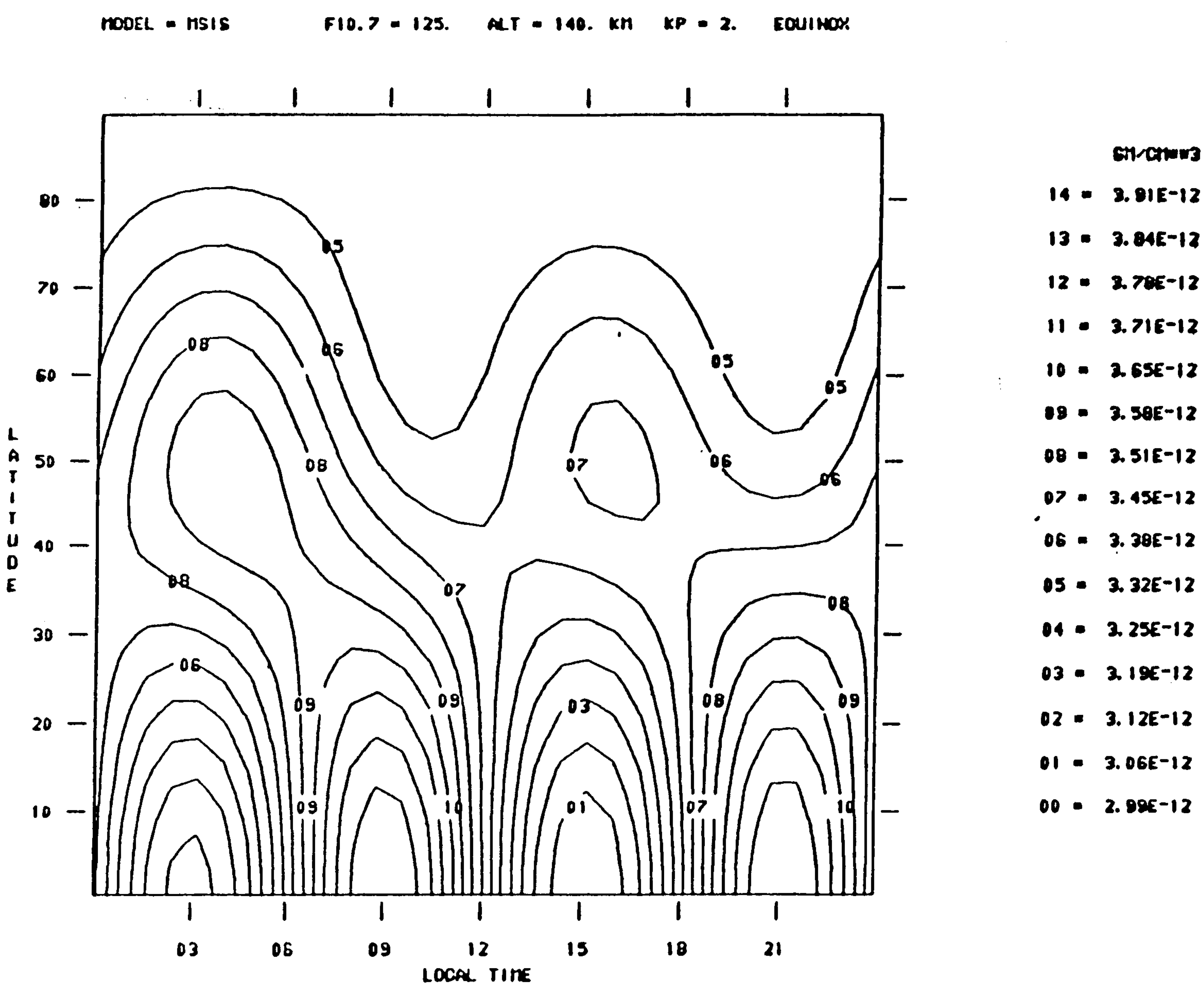

MODEL = MSIS F10.7 = 125. ALT = 140. KM KP = 2. EQUINOX
LATITUDE
80
70
60
50
40
30
20
10
LOCAL TIME
03
06
09
12
15
18
21
05
06
07
08
09
10
01
03
GM/CM**3
14 = 3.91E-12
13 = 3.84E-12
12 = 3.78E-12
11 = 3.71E-12
10 = 3.65E-12
09 = 3.58E-12
08 = 3.51E-12
07 = 3.45E-12
06 = 3.38E-12
05 = 3.32E-12
04 = 3.25E-12
03 = 3.19E-12
02 = 3.12E-12
01 = 3.06E-12
00 = 2.99E-12